(No Model.) 2 Sheets—Sheet 1.

E. THOMSON.

APPARATUS FOR REGULATING CURRENT OR POTENTIAL IN SECONDARY OF TRANSFORMERS.

No. 400,515. Patented Apr. 2, 1889.

Fig. 1.

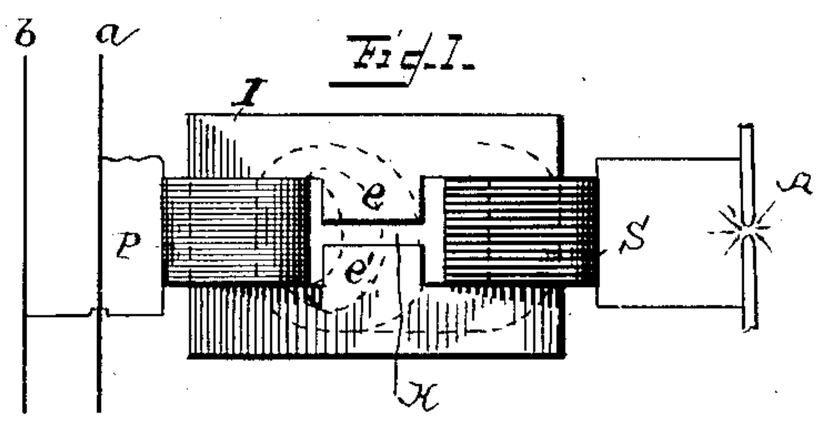


Fig. 3.

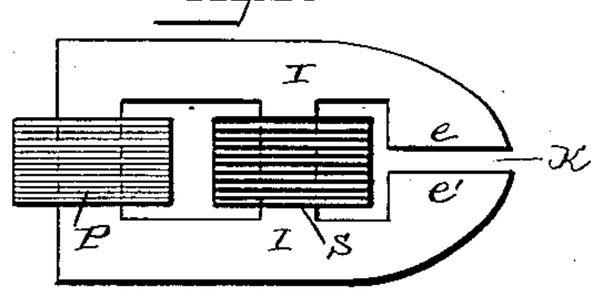


Fig. 2.

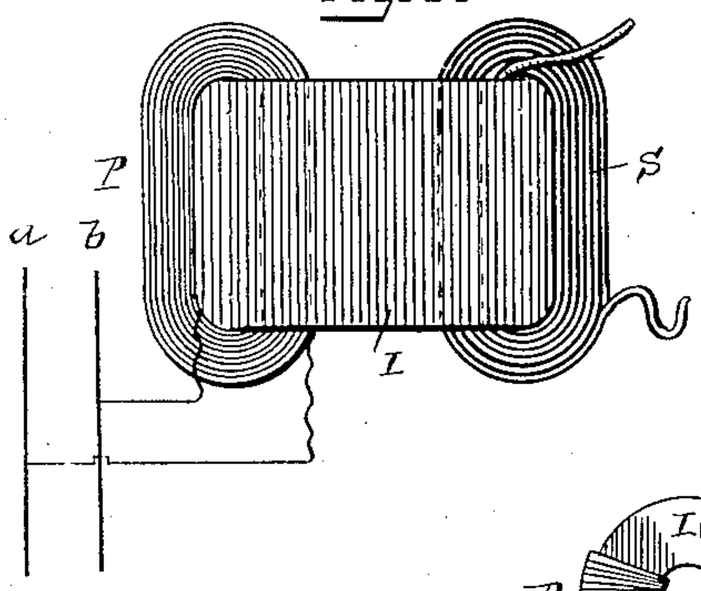


Fig. 4.

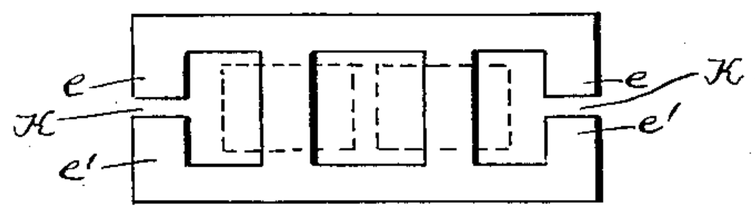


Fig. 5.

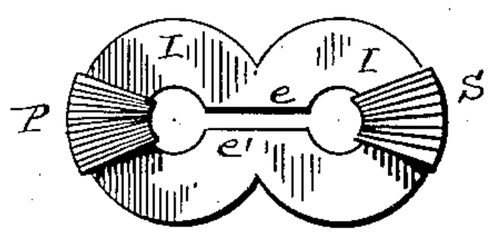


Fig. 6.

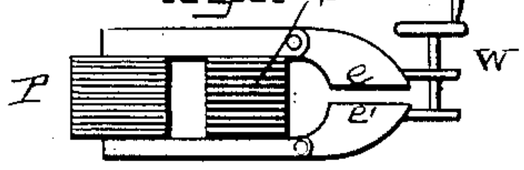


Fig. 7.

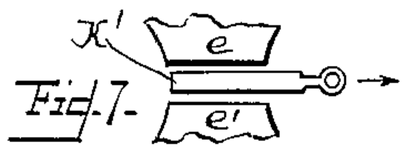


Fig. 8.

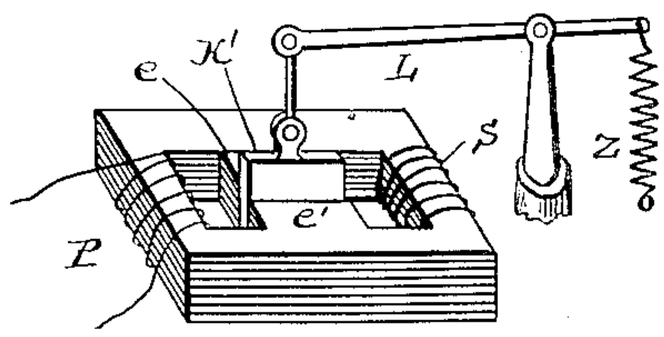


Fig. 9.

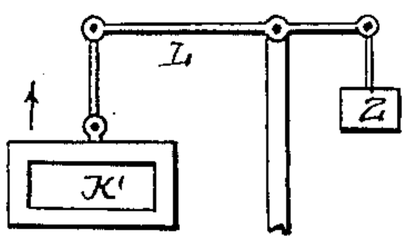


Fig. 10.

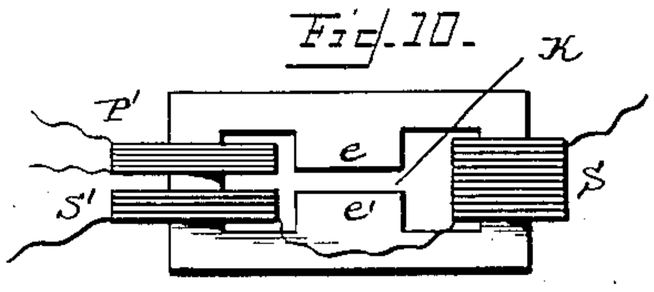


Fig. 11.

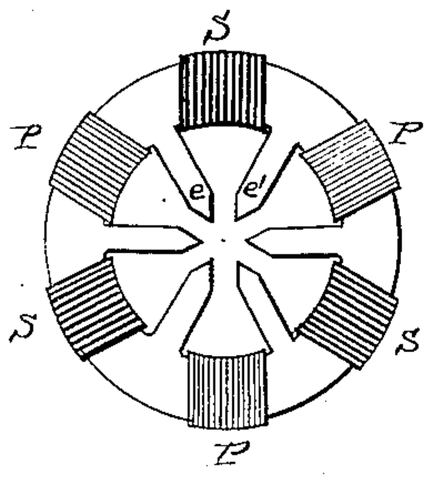


Fig. 12.

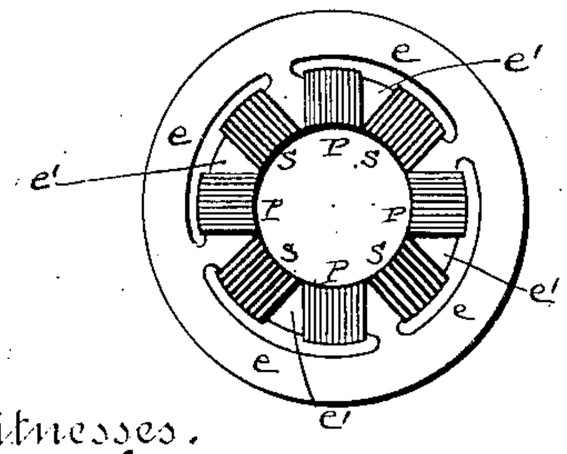
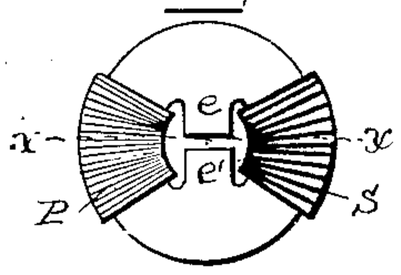


Fig. 13.



Witnesses.
Ira R. Steward.
Wm. H. Capel

Inventor.
Elihu Thomson.

By his Attorney
H. B. Townsend

(No Model.) 2 Sheets—Sheet 2.

E. THOMSON.

APPARATUS FOR REGULATING CURRENT OR POTENTIAL IN SECONDARY OF TRANSFORMERS.

No. 400,515. Patented Apr. 2, 1889.

Fig. 14.

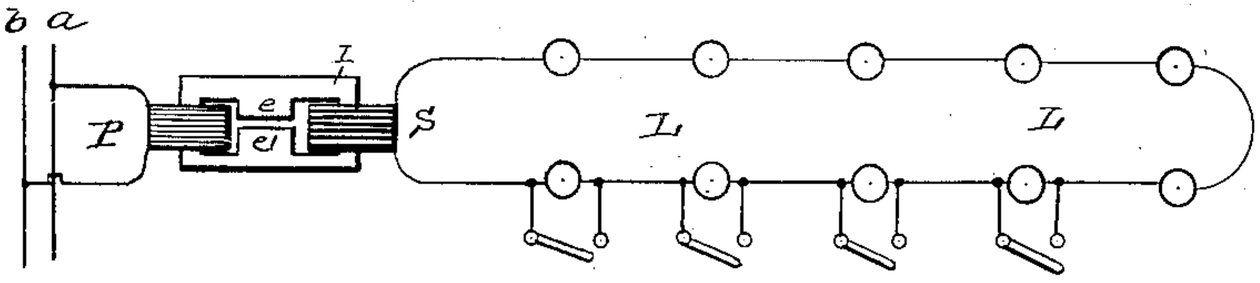


Fig. 15.

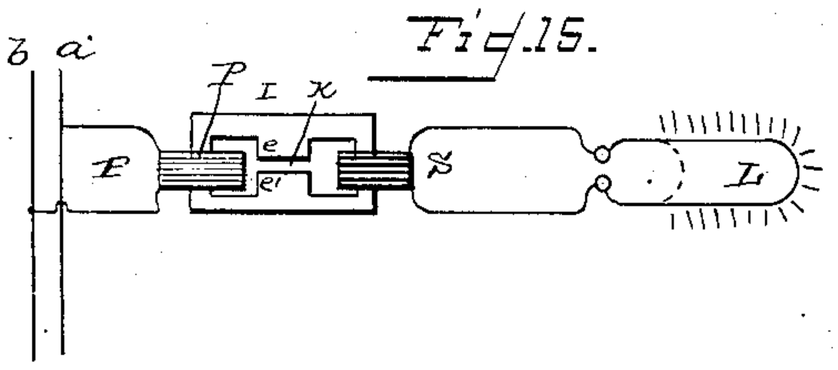


Fig. 16.

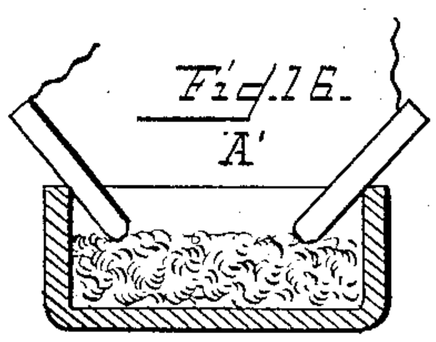


Fig. 17.

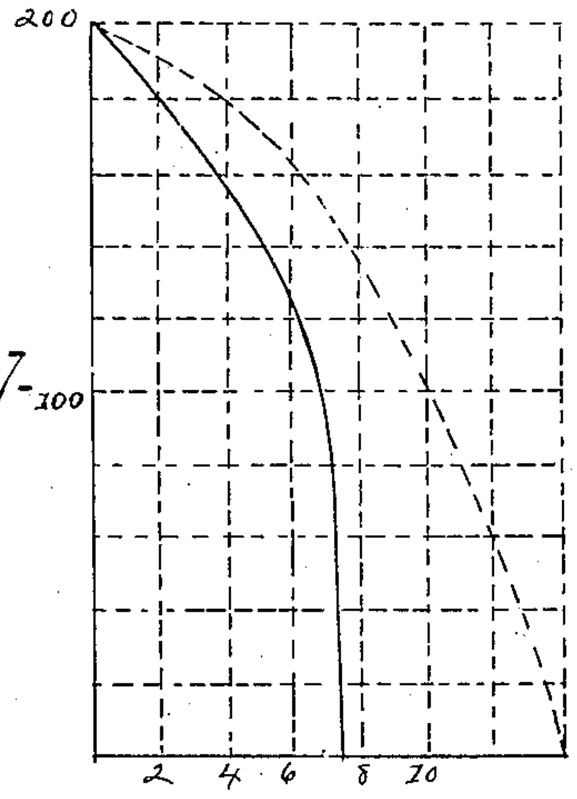


Fig. 18.

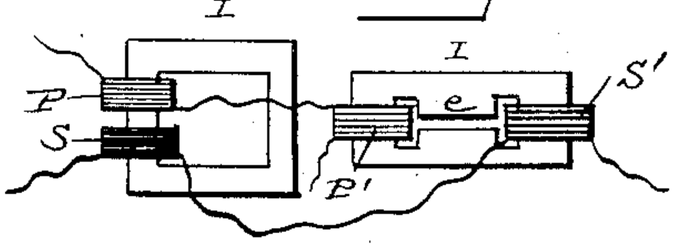
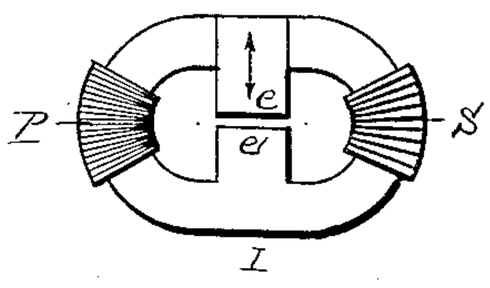


Fig. 19.



Witnesses.
Ira R. Steward
Wm. H. Capel.

Inventor,
Elihu Thomson
By his Attorney
H. G. Townsend

UNITED STATES PATENT OFFICE.

ELIHU THOMSON, OF LYNN, MASSACHUSETTS.

APPARATUS FOR REGULATING CURRENT OR POTENTIAL IN SECONDARY OF TRANSFORMERS.

SPECIFICATION forming part of Letters Patent No. 400,515, dated April 2, 1889.

Application filed January 10, 1889. Serial No. 296,018. (No model.)

To all whom it may concern:

Be it known that I, ELIHU THOMSON, a citizen of the United States, and a resident of Lynn, in the county of Essex and State of Massachusetts, have invented a certain new and useful Apparatus for Regulating Current or Potential in Secondary of Transformers, of which the following is a specification.

My invention relates to that class of electric apparatus in which two coils or currents are brought into inductive relation, one of said coils being the seat of alternating currents induced by alternations or other variations of current in the other.

The object of my invention is to so construct a device of this kind that it shall have a self-regulating character, resulting in an automatic adjustment or regulation of the current or potential in the coil forming the secondary when the resistance or current in the same varies. This self-regulating character is especially useful in cases where the inducing-coil is supplied from a source of constant potential, and by proper construction of the apparatus a regulation may be secured which will give a constant current in the induced circuit despite changes of resistance, although the inducing-current is connected continually to the constant-potential source. Thus if the primary coil of a converter be attached to a constant-potential circuit as a branch the current which I am enabled to obtain in the secondary circuit may, instead of being approximately of constant potential like the primary, be of approximately constant strength or volume of flow regardless of a wide range of differences of resistance interposed in such secondary circuit; or, again, I may obtain from the secondary an electro-motive force or potential which diminishes as the current strength increases, as when resistance is gradually taken out of the secondary circuit.

My invention is particularly applicable to the running of arc lamps by induction from constant-potential mains without the use of resistances in circuit with the arcs for limiting the current which they receive, since by the use of my invention any increase in the secondary may be made to produce a fall of electro-motive force given out by the secondary coil feeding the arc. Were this not the case, or were the electro-motive force maintained, the current flowing to the arc lamps would be unstable, and the lamps would be very irregular in action, owing to the fact that as the current in the arc increases the resistance of the arc falls, which would with constant potential bring about further current increase, and so on. In my invention if the current is to be ten ampères for the arcs it cannot rise much above that amount, no matter whether the carbons in the arc are apart or near together or in actual contact.

I am enabled also in my invention to operate a number of incandescent lamps or other translating devices in series from the secondary coil of a transformer and permit the shunting without resistance of one or more of the lamps while the current in the circuit of the remainder is substantially unchanged. In fact, by proper modifications in the manner of carrying out my invention, the primary coil being on constant potential, the secondary coil may be short-circuited and retain only the normal or a slightly-increased current. I am not aware that this has ever been done before.

My invention consists, essentially, in the combination, with one or the other or both circuits of the induction-coil, of an iron core which is included in the alternating or varying current circuit, and has parts, as hereinafter described, brought into definite proximity to form a partial magnetic closure of the magnetic circuit of said core of a definite or set value, according to the nature of the regulation of current or potential desired in the induced circuit, such magnetic circuit being formed independently of the magnetic circuit which threads both coils of the converter.

The invention consists, further, in a converter having primary and secondary coils disposed on different parts of the same core, parts or extensions of which are brought into definite proximity, so as to form a magnetic shunt of definite or set value for the part of the core included by each coil. The shunting thus provided will be automatically varied as the current in the secondary coil varies and will be increased in amount as the current increases, thereby automatically lowering the potential of the current delivered by such secondary.

My invention consists, also, in certain im-

proved details of construction and combinations of parts, to be hereinafter more particularly described, and then specified in the claims.

In the accompanying drawings, Figures 1 and 2 are elevation and plan views of a coil containing or operating in accordance with my invention. Figs. 3, 4, and 5 are modifications of forms of core. Figs. 6, 7, 8, and 9 show adjustable devices and modifications of the invention. Figs. 10, 11, 12, and 13 show modifications of forms and arrangement of the parts. Figs. 14, 15, and 16 illustrate some of the uses of my invention. Fig. 17 is a diagram showing current and potential. Fig. 18 shows modified devices giving similar effects to the foregoing. Fig. 19 is a form of adjustable core in one of my coils.

In Figs. 1 and 2, *a b* are alternating-current mains at constant potential difference, or approximately that.

P is a primary coil of insulated wire of turns corresponding to the potential between *a* and *b*, such that very little current passes in P when the circuit of S is open.

S is a secondary coil of suitable number of turns according to potential of current to be obtained therefrom. A laminated or other core, I, passes through both coils, P and S, as shown, and makes a closed magnetic circuit.

At *e e'* are projections from the laminæ of the core. By these projections the core is extended to include an air-space between the parts of the core at K. The width of this space K may be in some cases quite narrow, and in other cases *e* and *e'* may be well separated, as shown. The purpose is to provide an air or magnetic resistance-shunt to the parts of the core I, coming from the coils and joining their cores. The space K might be filled in whole or part with solid or liquid substances not highly magnetic, such as wood, paper, slate, &c. The coil so organized has the peculiar property of producing in the secondary coil S a droop or fall of electro-motive force when the resistance is cut out of its circuit, and this fall may be made nearly proportional to the fall of resistance, or diminishing resistance which may be inserted in its circuit.

At A is represented an arc lamp, (or A may stand for a series of arc lamps,) which may thus be fed with constant current, although primary coil P is subject to constant potentials.

By means of the projections *e e'* or other magnetic carriers or conductors the magnetism developed in the portion of core surrounded by the coil P can work, as it were, through two magnetic circuits, one including the space or resistance K and the other including the portion of core passing through the coil S. The magnetic lines developed by the core or coil P, which pass through the air-space at K and escape the coil S, produce wholly self-inductive effects, resulting in an opposition to the flow of the primary currents, while all the lines developed by the coil P, which pass through the axis of the coil S, result, as usual, in the production of secondary currents. Any tendency to increase of current flowing in coil P, resulting from the lowering of the resistance in the circuit of S, will at once be followed by increased self-induction of the coil P through the increased closure of the magnetic circuit of its core across the space K, while at the same time the self-induction of the coil S will also increase, owing to the increased closure of the magnetic circuit of its core across the same space. In fact, the effect of a slight increase of current in the coil S would be to beat back the lines of force tending to pass through its coils from the coil P and cause them to be shunted across the space K. The result of all this is that the varying resistance in the circuit of the secondary S receives a current which tends to be limited in strength and to be self-regulated through the provision of the shunting magnetic space K. The partial magnetic shunt at K may be also provided at other points than that shown in Figs. 1 and 2. In Fig. 3 it is at *e e'*, K being beyond the secondary coil S. In this case also the coils P and S might be interchanged in position on the core I I.

Fig. 4 shows a duplication of partial magnetic shunts at K K.

Fig. 5 shows a form of core I, Fig. 1, modified in outline, but producing similar results.

Fig. 6 shows faces *e e'* adjustable to and from each other by a screw, W, to vary the magnetic shunting, and thereby to vary the current induced in S. The nearer *e* and *e'* approach, the smaller the current given out in S, and vice versa. The distance affects but little the potential of coil S on open circuit; but when S is put to work its possible current becomes limited in accordance with the space between *e* and *e'*. I sometimes vary the action by inserting in the lines of force formed in the space of partial magnetic closure, as in Fig. 7, a conductor—such as a copper-plate, K'—to a great or less extent between the faces *e e'*. The effect is to cut off in part the passage of magnetism through the air between *e* and *e'* by the induction in the conductor of currents which oppose the magnetic effects. If, as in Fig. 8, the copper-plate K' be hung on a movable support, such as lever L, and be inserted part way between the faces *e e'*, as shown, the plate will when the current is on tend to be repelled from the slot. The spring Z may be adjusted to partly balance the piece K'. The addition of this device still further perfects the action in delivering a constant current, alternating, of course, from the coil S.

In Fig. 9, K' is a frame of copper, and Z is a counter-balance. This is used as in Fig. 8, K' being inserted in the space K, Fig. 1, and set so that when current is on coil P it is balanced in a position part way in the space K, as in Fig. 8, the secondary S being at the same time in circuit with its normal highest

resistance giving the normal current. Let this resistance be partly cut off and generally a slight increase of current will take place. The frame K′ moves outward from the slot (being repelled as an inductive closed circuit) and compensates for such increase, for a movement of K′ outward always results in a diminished current in coil S under any conditions. The apparatus by suitable balancing can thus be made accurately self-adjusting, so that a constant strength of current (average) is produced in coil S, unless the resistance interposed exceeds its proper limits. Where the current to be obtained is to have properties between those due to constant-potential average and constant-current average, the modification, Fig. 10, may be adopted. One coil, S′, or part of the secondary winding is near the coil P, or adjacent thereto, (or under or overlying the same,) and the other part of the secondary is, as at S, removed therefrom on the same core. In this case the terminals of the secondary coils in series will not either deliver constant potentials or constant current; but if the resistance in the secondary be diminished the current will increase but at a less rate than constant potential would give, so that a limited current of moderate strength flows even on short circuit.

Fig. 11 shows the invention applied to ring induction-coils. Between each primary coil P and secondary S′ the iron of the core is extended to approach and form a magnetic shunt of high resistance around each coil. In Fig. 12 the core itself is formed of an interior ring wound with coils P and S, &c., and an outer closely-enveloping ring, which may be joined between each alternate coil with the ring-core. The magnetic shunting occurs at *e e′ e e′ e e′ e e′*.

Fig. 13 shows a ring-core with only two coils, P and S, and magnetic shunt of comparatively high resistance at *e e′*. To construct the apparatus the core may be cut in halves or otherwise suitably divided, as on the line X X, and the coils wound separately and put in place over the meeting ends of the cores. In Fig. 19 this form is shown with means for adjusting the distance between the parts *e e′*. In this case *e* is made as a plug or sliding piece, which may be moved up or down to govern the space between the faces of *e* and *e′* or the resistance of the magnetic shunt.

Fig. 14 shows my improved induction-coil involving the feature of magnetic shunting, as before described, running a series of incandescent lights or other working resistances from the coil S, while coil P is on a constant-potential alternating circuit from *a b*. When the adjustments are properly made, one or even all the lights L L may be shunted by switches of no resistance, and the current in the circuit of S will be substantially unchanged in amount—*i. e.*, the potential of the coil S is self-adjusting to the resistance in the circuit unless the latter be too great.

Fig. 15 shows how a wire, L, may be maintained at a uniform temperature while its length in circuit may be greatly varied owing to constant current strength obtained notwithstanding constant potentials at *a b*.

For arc-light work or for electric furnaces or heating, as in Fig. 16, my invention permits distribution at constant potential to the coils and feeding to the work, as at A′, currents of constant volume, or, as before indicated, of a volume much less increasing than in the ratio of constant potential over the resistance in circuit.

Fig. 18 illustrates a modification in the manner of applying the device, Fig. 1, to primary and secondary circuits. The induction-coil P S is of ordinary or any suitable character, and the automatic regulation is produced by the coils P′ S′ in circuit with P S, respectively, and applied to a core with the partial magnetic shunt. The shunt operates in the manner already described to lower the potential of the secondary. In this case, however, as in Fig. 10, the droop of potential will not be in ratio to give a constant current; but the increase of current will be measurably limited by the action of the shunt for the core of coils P′ S′.

I do not herein claim the method of determining the current or potential in the secondary consisting in developing alternating magnetism through the action of the current in the primary or secondary, or both, and variably closing the magnetic circuit through a path independent in whole or in part of the core in which magnetism is devoloped by the other coil, as this method forms the subject of another application for patent filed of even date herewith.

In Fig. 17 the verticals or ordinates may represent potentials developed in a secondary, S, with varying resistances, and the horizontals or abscissas the strength of the currents flowing. The continuous curve line starting at two hundred becomes nearly vertical at one hundred, showing that from this point down at any less potential than one hundred the current will remain practically the same. The dotted or broken curved line shows the condition of partial regulation in which there is a continued fall of potential accompanying an increase of current. These curves may be called "characteristics" of the apparatus, and will vary, as before stated, according to the construction and proportions.

What I claim as my invention is—

1. An induction-coil or transformer having a partial magnetic shunt of determinate capacity for the magnetism threading the coils, whereby the potential of the secondary current may be automatically lowered on an increase of such current, as and for the purpose described.

2. In an induction-coil or transformer, a par-

tially-closed magnetic circuit consisting of polar extensions or magnetic carriers from the parts of the core between the primary and secondary brought into close proximity, as and for the purpose described.

3. The combination, with an induction-coil or transformer having a magnetic shunt, of a conductor suspended or movable in the shunting-lines of force, as and for the purpose described.

4. The combination, with constant-potential mains, of a transformer, a secondary for said transformer feeding translating devices in series, and a magnetic shunt for the transformer having a definite or determinate capacity, such as described, proper for limiting the currents in the secondary, so as to keep or tend to keep the same of constant amount, as and for the purpose described.

5. The combination, with an iron core threading two alternating-current coils, of magnetic carriers or extensions for said core brought into close proximity and forming a magnetic shunt variable in amount automatically by the increase or decrease of current in one of said coils, as described.

6. The combination, with two alternating-current coils placed in inductive relation upon a suitable core, of a magnetic shunt for the magnetism threading said coils and of definite or determinate strength increasing automatically with an increase of current in the coil.

7. The combination, with two alternating-current coils wound on different parts of the same core, of iron masses tending to form a magnetic shunt for the portions of core between the coils and adjustable for the purpose of determinating the amount of the magnetic shunting.

8. The combination, with constant-potential mains, of a transformer having its primary fed therefrom, a secondary on a different portion of core, and a partial magnetic shunt for the portion of core between the coils.

9. The combination, with the primary, of two secondaries connected in series and applied to different parts of the same core, one near to and the other more remote from the primary, and a partial magnetic shunt for the core, as and for the purpose described.

10. The combination, with two alternating-current mains, of transformers having a variable resistance in their secondaries and partial magnetic shunts for the portion of cores threading the secondaries, as and for the purpose described.

11. A system of distribution for arc lighting, comprising constant-potential mains, transformers in multiple on said mains, arc-light circuits connected to the secondaries, and potential-regulators consisting of partially-closed magnetic circuits set up by the currents of either or both of said coils.

12. The combination, with primary and secondary alternating circuits in inductive relation, of an iron core forming a seat of alternating magnetism developed by one of said circuits, and having extensions brought into close proximity to form a partially-closed magnetic circuit of determinate amount variable automatically with the currents flowing.

13. The combination, with primary and secondary alternating-current circuits in inductive relation, of an iron core forming the seat of alternating magnetism developed by the current in the secondary and extensions from said core brought into proximity to form a partially-closed magnetic circuit of definite or determinate amount.

14. The combination, with an alternating-current main, of a transformer having a variable resistance in its secondary and a core which forms the seat of magnetism developed by the secondary currents, and is provided with extensions brought into proximity to form a partially-closed magnetic circuit of determinate amount, as and for the purpose described.

15. The combination, with an induction-coil or converter, of a partially-closed magnetic circuit excited by the current in each or either of the electric circuits and a conducting-plate movably suspended in a gap in such magnetic circuit, as and for the purpose described.

16. The combination, with an induction-coil or converter, of magnetic carriers—such as iron-core extensions—from a core excited by the current which flows in one of the coils of the converter, and means for adjusting the magnetic resistance between the parts of the core partially shunted by said carriers or extensions, as and for the purpose described.

17. An induction-coil or converter having an endless iron core or magnetic circuit on which the primary and secondary coils are disposed at different points, and having parts or extensions of said core brought into determinate magnetic inductive proximity to form a partially-closed magnetic circuit of definite capacity independent of the closed magnetic circuit over the iron core and through the coils.

18. An induction-coil or converter having primary and secondary conductors wound on different parts of the core, and having parts of said core brought into proximity but separated by a magnetic shunting-space of definite or determinate capacity, as described, proper for keeping the current in the secondary approximately constant when the primary is supplied from a constant-potential source.

Signed at Lynn, in the county of Essex and State of Massachusetts, this 31st day of December, A. D. 1888.

ELIHU THOMSON.

Witnesses:
J. W. GIBBONEY,
E. W. RICE, Jr.